A HYBRID BIO-GEOGRAPHIC AND GENETIC ALGORITHM FOR ENERGY EFFICIENT CLOUD JOB SCHEDULING

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of
DOCTOR OF PHILOSOPHY

by

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MANAV RACHNA UNIVERSITY

Year 2026

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I hereby declare that the short synopsis entitled "A Hybrid Bio-geographic and Genetic Algorithm for Energy Efficient Cloud Job Scheduling" being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in the Department of Computer Science & Technology under the School of Engineering of Manav Rachna University, Faridabad during the academic year 2025-2026.

It is the work that is expected to be carried out under the supervision of Dr. Sachin Lakra.

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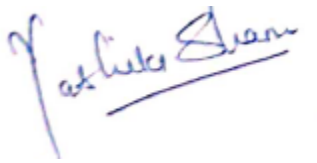

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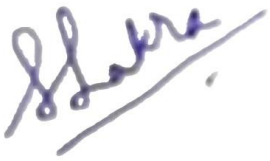

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ABSTRACT

In the emerging era of technology and online services, the Internet, with its grounding in Cloud Computing infrastructure, has become an important constituent of the day-to-day life of human beings. Both these technologies use data as their raw material and they provide data processing as the service to their users. With time, data has grown in volume and due to this large volume of data on the Internet, it has been termed as “Big Data”. Due to the huge amount of data which requires processing, the development of new cloud computing infrastructure has progressed very quickly. Every organization which performs data processing requires both hardware and software, which are made available by the cloud as pay-per-use services. Since data is now of utmost importance, it needs to be secured from malicious use as well as theft. Due to the increasing traffic of data across the cloud, processing has to be done in an efficient manner by prioritizing the task. Data processing requires efficient algorithms for each of its subtasks. One of the most important tasks for efficient data processing is scheduling the processing of these tasks based on the time at which different users submit their tasks and on the urgency of completing them. Scheduling further involves the tasks of load balancing and resource allocation. The objective of this research work involves the task of load balancing and resource allocation by applying nature-inspired algorithms. The task has been done by combining the Biogeography-based Optimization Algorithm with the Genetic Algorithm. With the help of this optimization, the energy requirement of any cloud computing environment is also reduced, helping the infrastructure to become greener.

Keywords: Cloud Computing, Load Balancing, Green Computing, Genetic Algorithm, Biogeography-based Optimization Algorithm

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1 Introduction

Many daily tasks which are done by people in today's world are completed with the help of devices – be it applying for a job, reading the news, or even watching movies. With the development of artificial intelligence (AI), technology has gained speed in its adoption and use. Similarly, AI has also been merged with the cloud – and the cloud has become accessible to users through small devices, such as the mobile phone. These small devices, available in different forms [1], are hand-held and easy to use, and can even be used to setup a small network in a home.

In 1992, Tim Berners-Lee created the first webpage – thereby laying the foundations for the next technological revolution, namely, the world wide web. Internet-driven technologies are mostly founded on a cloud infrastructure.

Scientific discoveries and technological inventions are always like double-edged swords – having both positive as well as negative impact. An exponential increase in the use of computing devices has led to an unprecedented rise in carbon footprints. Carbon footprints indicate the extent to which computing devices are contributing to global warming – affecting both humanity as well as nature. Another new technology which has a huge impact on global climate is a data center. A data center uses a huge amount of energy to operate its large number of servers to handle cloud requests. This leads to the requirement of developing technology which is green and uses green computing concepts.

Green computing gives the direction to the IT industry to move towards sustainable and energy efficient technology. This transition is required to reduce the environmental hazard being caused due to the growth of the use of technology. There are various ways through which this transition can be achieved. The hardware approach is the first one – minor changes in the design of an electronic device may result in a sustainable hardware design. Recycling should be encouraged to meet the challenge of managing e-waste. The software approach is another approach and may have a broader impact on resolving the issue of global warming. The concept of virtualization, and optimizing the cloud computing load balancing and scheduling processes, may be a step towards achieving sustainability.

Computing services are today available for a small amount of money. These are provided to users globally through the cloud. These services include storage of data, data

processing and software for different purposes in the form of mobile apps. Such apps and services are helpful to both the public as well as to business users. Any user wishing to use these services submits a request to the cloud. The cloud fulfills these requests as per availability of resources. These services are collectively known as “Cloud computing” services [2].

The cloud provides these services in 3 different forms. Each of these forms follows the concept of pay-per-use. The first, named as Infrastructure-as-a-Service or IaaS, provides hardware to users who do not wish to purchase a device for their individual use. These services are available to users at any location across the globe. Platform-as-a-service or PaaS, provides software including a programming language as well as new AI tools to users without the need to download or install them. Software-as-a-Service or SaaS, includes making daily use software such as Google Sheets, Google Docs, etc., available through the cloud without any payment or any specific hardware. Users may need to pay a small subscription fee and use the software. Without cloud computing services users were required to purchase software, download it on their personal device and then use it. In addition to this, a purchased software needed maintenance by a software expert with regular updations being made to the software. As a result, the users’ focus turns towards having the software maintained rather than on their own work. With cloud computing users are given a solution which allows them to focus on their work and that too at a very nominal cost.

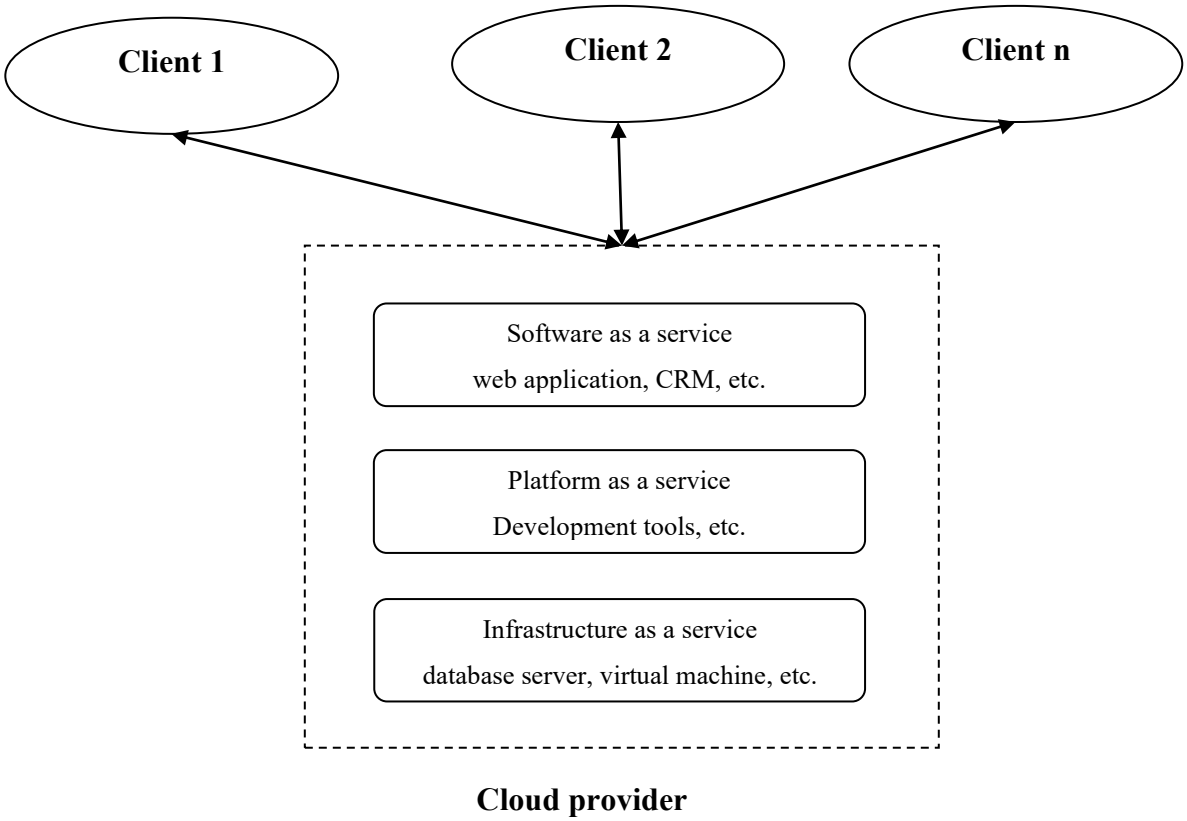

Figure 1 Architecture of Cloud Computing

1.1 Hybrid cloud

Hybrid cloud is an integrated framework that combines public Network, Private Network and the underlying infrastructure to provide flexible and cost-effective IT solutions to users. This integration allows the organizations and users to have benefits of different cloud environment. It also offers secure packages to handle the sensitive data and information while maintaining the integrity and confidentiality of the organizations. With huge organizations and a large number of users involved, there is a possibility of a cloud burst situation. A cloud burst occurs when the underlying infrastructure fails to handle the large number of incoming user requests with the available resources. A hybrid cloud handles the

situation by delegating the task of a company's private cloud to the public cloud for the time being.

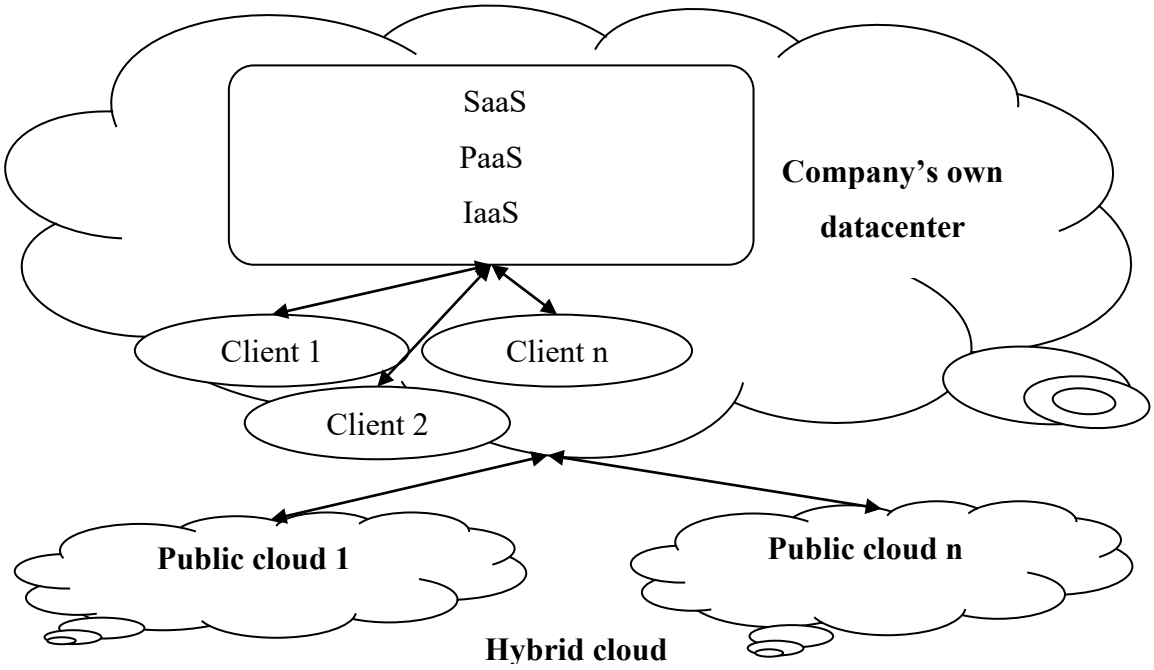

Figure 2 Structure of Hybrid Cloud

Table 1. Comparison between development models

Deployment Model	Infrastructure Manager	Infrastructure Owner	Infrastructure Location	Accessibility & consumer
Public	"Third party"	"Third party"	"Off-Premise"	"Un-trusted"
Private	"Organization or third party"	"Organization or third party"	"On premises or off premises"	"Trusted"
Hybrid	"Both organization & third party"	"Both organization & third party"	"Both on premises and off premises"	"Trusted & Un-trusted"

1.3 Features of cloud computing

The essential features of any cloud computing setup are as follows:

1.3.1 On-Demand & Self provisioning

On demand refers to the flexibility of the cloud computing environment. It is available whenever the users require it. User needs are not fixed, rather they are random, and tend to change quite often. Therefore, cloud services are said to be on demand, since they are available whenever users desire to access and use them.

1.3.2 Shared Infrastructure

The whole cloud infrastructure is not dedicated to a single user rather it is shared among various users according to their needs. Priorities are assigned to the user requests and the resource allocation is done on the basis of priority of user request. Available resources should be utilized to their maximum capacity to meet user requirements.

1.3.3 Dynamic Provisioning

Dynamic provisioning refers to the allocation of cloud resources dynamically. User requests are not static rather they are dynamic. Resources need to be provided as and when there is a request for the resources. Every job has unique resource requirements in terms of CPU cycle, memory and bandwidth. Resource allocation needs to be done in accordance to these requirements and till the complete execution of the task. Jobs carrying sensitive information need to be taken care of accordingly.

1.3.4 Network Access

Cloud services are accessible wherever there is an active network irrespective of the physical location of the user or the type of device the user is using. The services are available for all classes of devices, viz., desktops, laptops, handheld devices and other smart devices. Routine as well as enterprise services are available for all users across the network.

1.3.5 Resource pooling

The cloud facility includes issuers, which perform the task of pooling computing resources to handle the requests of a small set of consumers. A muti-user system, with an exclusive set of physical and digital resources, dynamically assigns and releases the resources in accordance

to user requirements. Resources across the globe are pooled together giving the user a sense of location-independence as these resources are allocated to the user in the same way – irrespective of the location from where it was requested.

1.3.6 Elasticity and Flexibility

A cloud computing environment has a constant flow of data as well as of user requests. But this incoming traffic is non-linear in nature. It may sometimes be much higher than anticipated and may require additional resources. Sometimes there may be an underflow and resources may be idle resulting in the increased downtime of the resources. This non-linear flow of traffic needs a flexible system to handle the traffic smoothly and cloud infrastructure is ready for this flexibility.

1.4 Challenges

Cloud computing offers various features but along with them it also poses certain challenges. These include safety and security challenges related to data and user requests. The challenges are due to the lack of standard operating procedures.

1.4.1 Data location

Virtualization of cloud computing allows the server to operate from different locations globally. Data location is dependent on the resource availability. Users and organizations are unaware of the exact location of the data storage and processing. However, there are certain cloud service providers (CSPs), which may provide the location of the stored data to the organization.

1.4.2 Cloud security policy

All CSPs provide different levels of transparency to the users due to differences in the security policy of individual CSPs. There is no standard protocol laid down to define the level of transparency a CSP has to provide; rather a Service Level Agreement (SLA) defines the transparency and security constraints required by the organization.

1.4.3 Lack of standards

Although the cloud interface may be documented but till date there are no standards available to govern the working of clouds. The lack of standards inhibits the intercommunication among the clouds as each cloud may be operating at different standards.

1.4.4 Continuous growth

Customer needs are not static rather they are continuously changing and evolving – and so is the cloud environment. A cloud's infrastructure is continuously growing to accommodate the growing trend of clients' requirements.

1.4.5 User authentication

Cloud data may be sensitive as well as critical to varying degrees depending on its type. Since data is available globally, its security becomes an important matter. Every user can usually access his/her own data or must be authorized to access other data. This task of giving authority is implemented on the cloud with the help of authentication mechanisms at different levels. Usually, in an organization, a higher level user is able to access data of lower levels but the vice-versa is not permitted. To maintain reliable access across the cloud, user authentication, with the help of mechanisms such as username-and-password, etc., is required.

1.5 Cloud Scheduling

This mechanism provides an efficient and low-cost way for handling user requests as well as allocation of resources to these requests. The task of scheduling has been an area of research for a long time and has evolved with the writing of different algorithms, while improving them over the years. A number of algorithms have been written to handle scheduling of tasks with the objective of improving request management and the increasing volume of these requests. Another objective has been to reduce the impact of the waste heat produced by the processing done by the cloud infrastructure on the environment. However, the cloud infrastructure is very unpredictable since it is non-linear and is not optimized.

2 Literature Review

Dastjerdi, et al, in [4], present the need of a complete framework to handle the cloud infrastructure and that a single solution cannot handle all the services provided by the cloud. They further state that this framework must be flexible as well as compatible with different types of systems in use globally. Also, since a number of vendors provide their services to potential users, the users themselves find it difficult to choose the right one. Not only this, users have different levels of expertise in using these services and also have different requirements. As a result, the framework must be flexible as well as distributed. Thus, the

paper presents such a framework, intending to provide diverse users with a feasible and the right mix of solutions.

Hung, P.P. et al, in [5], describe a requirement of server synchronisation in data centres to provide high availability and making the cloud environment more reliable. This synchronisation, in turn, provides multitasking. But it requires efficient methods to handle the multitasking and the synchronisation of the virtual machine but it does not always guarantee the required performance. In this paper, the authors have developed certain scheduling regulations based on the bandwidth requirements to emphasize on the sustainability of a cloud computing environment. The algorithm now not only best considers the community bandwidth, but also takes into consideration an economic price. The proposed work is justified through considerable simulations and comparison of findings with other existing studies. The future work mentioned can lead to enhancement of the advantages in their technique.

Menzel, M. et al, in [6], emphasized on the need of a more accurate and efficient system to catch the needs of huge user requirements and continuously increasing amount of data on the Internet. The solution should be such that it completes user requests without any compromise on the performance and the overall cost of the system. In this paper, the authors give an evolutionary migration method aimed at internet software clusters allotted for more than one site, and clearly pick out the most vital standards relevant to the selection problem. Furthermore, they give a multi-criteria based choice set of guidelines based totally on the Analytic Hierarchy System (AHP).

Prasad, A.S. et al, in [7], presents a method for automating the resource selection process. The presented technique, although not highly efficient, involves dynamic pricing as a part of the solution. The paper presented 3 methods for resource allocation on the cloud, namely, Cloud-Dominant Strategy Incentive Compatible (C-DISC), Cloud-Bayesian Incentive Compatible (C-BIC) and Cloud Optimal (C-OPT). The C-DSIC technique uses the VCG mechanism, while C-BIC attempts to strike a balance between prices and ranges. The C-OPT method identifies the winning vendor on the basis of least virtual charges, whereas the former 2 techniques identify the winner on the basis of the price per unit QoS. Based on the experiments conducted by the authors, the paper concludes that the resource purchase cost

would decrease with an increase in the number of cloud vendors. This mechanism will help users in choosing the vendor providing the most suitable services at minimum cost.

Rahman, M. et al, in [8], discusses the exponential growth in data and number of users with the advancement of technology. This huge amount of data and users may lead to a cloud burst like situation. Hence, he emphasizes the need of an efficient and dynamic load balancing mechanism to cater to the increased demand. Lamentably, there are no papers focusing on the technology of a Load Balancer as a Service (LBaaS), and the assessment of its performance. In this paper, they first recognize the principles of load balancing, its significance and desired traits in the cloud. Then they offer a complete evaluation on the prevailing load balancing strategies, their power, shortcomings and a comparative study. In the end, they present an LBaaS version followed by means of the use of the most vital marketplace players, and their statement, future desires and challenges.

Sarbazi-Azad, H. et al, in [9], describes the main challenges faced by the enterprise whilst adopting cloud computing as a mainstream strategy. It provides an application-oriented cloud model for realizing a marketplace-oriented cloud computing vision. CloudBus found this out through developing various tools and structures that may be used individually or together as an included answer.

Wadhwa, B. et al, in [10], describe cloud computing as an IT technology which is emerging at a fast pace. The paper emphasises on the user friendliness and simplicity as the contributing factors for its popularity. But, with its widespread usage it leaves a significant carbon footprint behind. Therefore, there is a need of a more clean and sustainable cloud approach which can minimize the carbon footprint. It can be achieved by virtualization and effective migration of user jobs across the VMs.

Yuan Feng et. al, in [11], describe how IaaS cloud businesses have begun to offer cloud computing offerings, since a competitive market is emerging to compete for users who want to use these types of services. Because of different capacities and company workloads, users may additionally have a look at how to complete their cloud computing tasks and in all kinds of stages of provider functions. To increase the number of cloud clients, it is important for every cloud issuer to choose a "maximum dependable" price such that the required quality corresponds to the provider’s quality, while being attractive to customers. In this paper, the

authors present a scenario of this form of a marketplace with multiple competing IaaS cloud companies.

Zohar, E. et al, in [12] elaborate on PACK (Predictive ACKs), a unique prevent-to-quit site Traffic Redundancy Elimination (TRE) system, which was designed primarily for customers using cloud computing. Cloud-oriented TRE requires the application of a method of using cloud sources so that the bandwidth charge reduction, mixed with the additional pricing of TRE calculation and storage, might be optimized. PACK's vital benefit is its functionality of reducing the load on the cloud-server TRE, consequently minimizing the processing expenses brought on as a result of the TRE's rules. In contrast to previous resolutions, PACK does not need the server to constantly keep upgrade rules for clients.

3 Problem Statement

Scheduling in cloud computing is a challenging task considering the flexibility and the amount of data involved. It is not feasible to manually allocate the task to the resources for their execution. To utilize the cloud environment and infrastructure scheduling needs to be optimized. Cloud scheduling and load balancing is crucial for the cloud environment as an effective scheduling mechanism ensures that all the resources are being utilized efficiently and that no idle resource is prevented from being provided to a user request at a particular point of time. Scheduling algorithms can be static or dynamic. Static algorithms are generally suited for an environment where the user jobs are of similar types or the trend is predictable. With an ever-increasing demand of internet and cloud services and the fact that catering to them does not appear to be feasible, there is a requirement of dynamic scheduling algorithms. Scheduling algorithms are required not only to allocate resources to the incoming jobs but to make the overall system a cost effective and an environment friendly computing solution.

3.1 Optimization as a Solution to cloud scheduling

Biogeography based Optimization (BBO) is a nature inspired metaheuristic method for solving optimization problems. It is based on the trend of biogeography that describe that species migrate between different habitats with emerging different demands of food shelter safety, etc. The migration of species to new habitats may result in emergence of new species and eventually this migration may also lead to extension of the migration of some species

due to non-suitability of the new habitat's conditions for that species to survive. Habitats providing more support for survival have a high Habitat Suitability Index (HSI). There are several factors that influence the HSI.

HSI is a very abstract term in terms of species. An area suitable for one species may not be for the other. In contrast to cloud computing environments not every resource is meant for all the jobs. All jobs have their particular requirements and resources needs to be allocated according to the nature of the jobs. There are various factors that determine the suitability of a resource for a particular job like the execution time, the amount of data, the type of data as well as the confidentiality and sensitivity of the data which the job is carrying.

The BBO algorithm is an effective solution to the scheduling mechanism of the cloud computing environment, providing it flexibility and a parallel processing mechanism. Thus, the problem statement for this research work is stated as follows:

To optimize cloud job scheduling algorithms using a hybrid Biogeography-based and Genetic Algorithm so as to enhance the energy efficiency of the scheduling task.

4 Research Objectives

Based on the problem statement, the research work has the following objectives:

RO1 To propose an energy model of a cloud system where the energy is defined in terms of the throughput of the overall system and resource utilisation.

RO2 To analyse the BBO and genetic algorithms to assess their efficacy in a cloud based environment.

RO3 To implement the hybrid BBO and GA based algorithm and conduct experiments to show its optimality for scheduling.

RO4 To compare the hybrid algorithm and compare it with existing algorithms.

5 Research Methodology

Cloud computing solutions that not only limit operational prices but additionally reduce the impact of the cloud on the environment, are the need of the hour. This work is centered on the layout and implementation of an automatic scheduling that achieves better stability. To effectively gain the research goals the BBO based set of rules will be implemented in MATLab and a comparison of its performance will be done with equivalent techniques.

5.1 Architecture of Scheduling and Load Balancing

Figure 3 depicts the design of the scheduler and the load balancer in the proposed method. The Load Balancer (LB) receives the job and allocates it to the most appropriate VM according to the pre-decided criteria. The criteria may be a fitness function or a given set of rules according to which the arriving tasks are allocated to the VMs at the time of execution. No VM or resource should be idle at any instance and it is the responsibility of an LB to ensure that no job should be in waiting – if there is a resource available. There is a predefined criteria of suitability according to which the resources are allocated as different jobs have unique resource requirements. Not every resource is suitable for every incoming job. Each incoming job carries the information of its requirements regarding the type of resource, its execution time, memory requirement, etc.; the LB allocates resources accordingly.

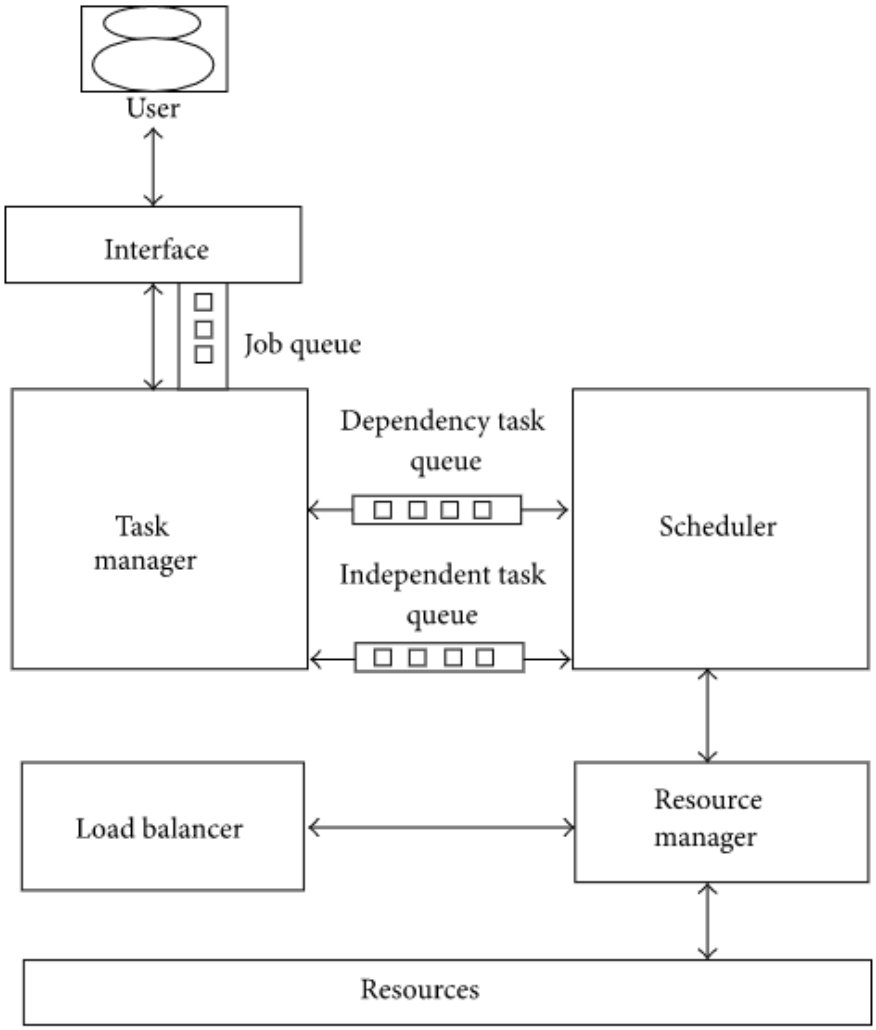

Figure 3 Architecture of Resource Allocation via Load Balancing and Scheduling

5.2 Working of a Load Balancer

The working of a load balancer is depicted in Figure 4 below.

Step 1: Importing Work load traces:

The working of a LB starts with importing logs of OpenCloud. Table 2 depicts original raw logs from an open source framework of Hadoop.

Step 2: Preprocessing of Work load Traces:

Raw data contains noise and redundant data. There is usually, some unwanted information as well in the raw data, therefore, preprocessing is required to filter the dataset and to eliminate the noise.

Table 2. Job history [15]

Field name	Data type	Description
jt_id	int8	
Job_id	int8	
submissionTime	int8	UTC timestamp(ms)
launchingTime	int8	UTC timestamp (ms)
finishingTime	int8	UTC timestamp (ms)
Status	tinyint	SUCCESS: 3, FAILED: 3, KILLED: 5
Num_Maps	int4	total no. of map tasks in the job
Num_Reduces	int4	total no. of reduce tasks in the job
Fin_Maps	int4	No. of completed map tasks in the job
Fin_Reduces	int4	No. of completed reduce tasks in the job
Fail_Maps	int4	No. of failed map tasks
Fail_Reduces	int4	No. of failed reduce tasks

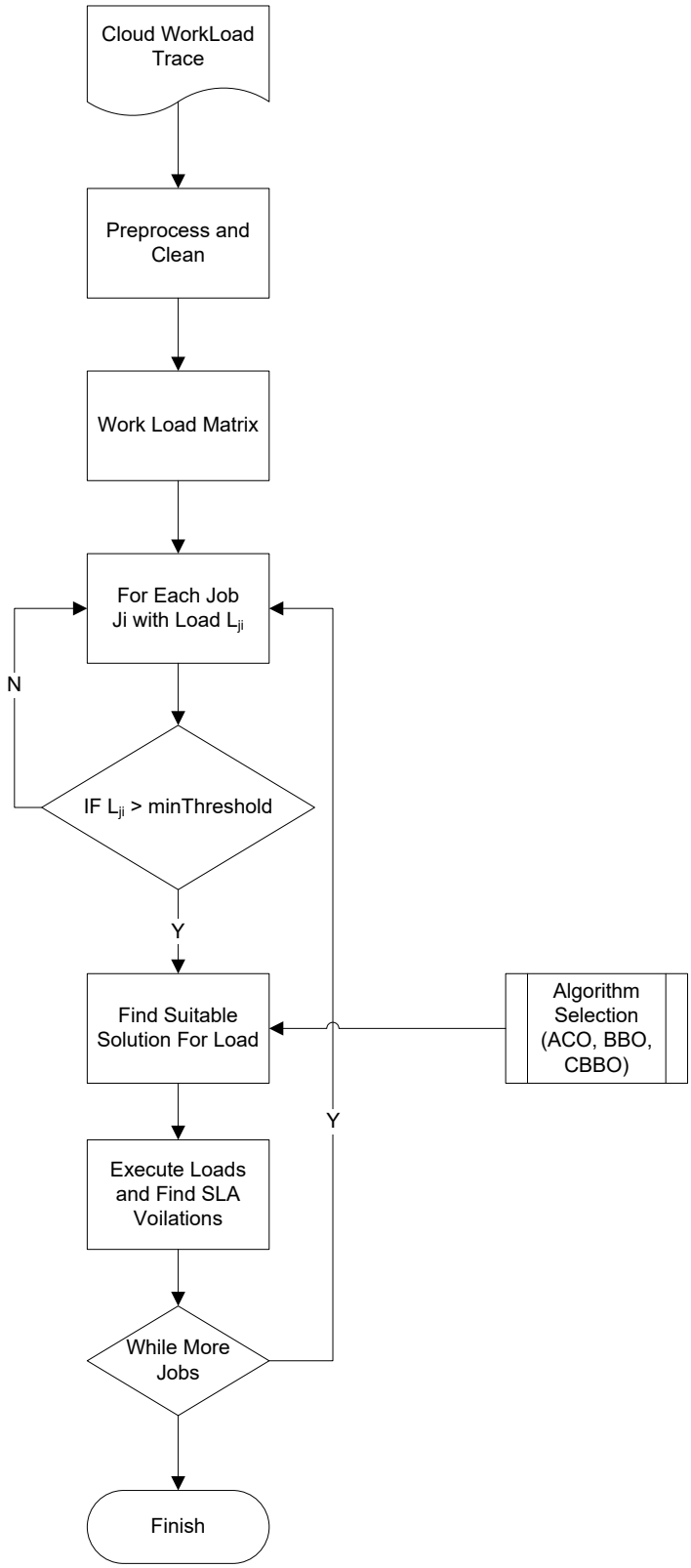

Figure 4 Proposed Flow chart of the Green Cloud Load Balancing Algorithm

Step 3: Creation of workload matrix

After preprocessing a workload Matrix needs to be prepared that can be fed into the MATLan Integrated Development Environment (IDE). The workload material is created using Hadoop logs. The workload matrix is supplied to MATLab and the optimization algorithms are then applied.

Step 4: Optimization

Log items from the test matrix are selected and run for the selected optimization algorithms like ACO, BBO and GA-BBO algorithms. This step provides the threshold of the balancing cost of the algorithm and selects the optimal job to be allocated to the VM.

Step 5: Assignment and Evaluation

The fittest job is selected and assigned to the most suitable resource. After successful execution various factors are evaluated to check whether the job was executed within the time frame or not, and to assess the computing cost required and the energy consumed during the execution, as well as the throughput of the execution process. A comparative analysis of the applied algorithms to check which algorithm was best suited and consumed the least amount of energy, while providing the highest throughput.

6. Expected outcome of the research

An energy efficient automatic scheduling algorithm based on load balancing having better performance both in terms of throughput and energy efficiency in comparison to the current similar techniques.

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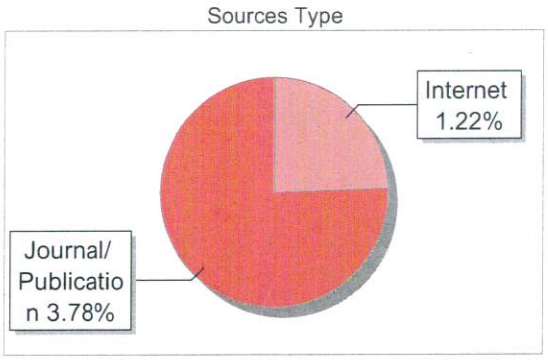

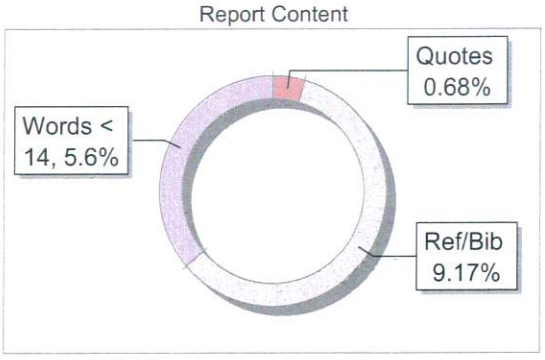

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A HYBRID BIO-GEOGRAPHIC AND GENETIC ALGORITHM FOR ENERGY EFFICIENT CLOUD JOB SCHEDULING

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of
DOCTOR OF PHILOSOPHY

by

Ms. Yashika Sharma
Registration No. MRUCSDN012K230065

Under the supervision of
Dr. Sachin Lakra
Professor

MANAV RACHNA UNIVERSITY

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ABSTRACT

In the emerging era of technology and online services, the Internet, with its grounding in Cloud Computing infrastructure, has become an important constituent of the day-to-day life of human beings. Both these technologies use data as their raw material and they

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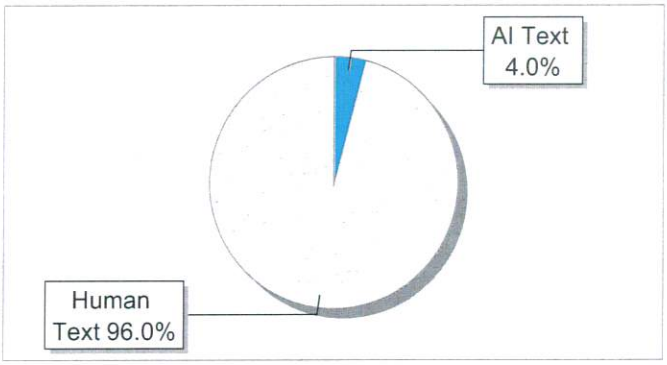

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